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MEASUREMENT AND MODIFICATION OF SENSORIMOTOR SYSTEM FUNCTION DURING VISUAL-MOTOR PERFORMANCE

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Studies conducted during the initial phase of this project had two major objectives. The first was the selection of a visual-motor performance task that met the needs of a) long term operation, b) physiological and functional appropriateness, c) relevance to the Air Force mission, and d) feasibility within the resources available to us. Towards this end four video games were tested on each of six adult subjects. Evaluation of these tasks as well as EEG correlates of performance led to the selection of one for subsequent studies. Our second objective was to determine if the quantitative analysis of somatosensory EEG

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characteristics could yield information predictive of performance. Preliminary findings indicate that specific frequency components do, indeed, change in relation to response accuracy and speed. These consistent observations provided support for our basic assumptions and will guide the focus of subsequent studies.

INTRODUCTION

New methods for the quantitative analysis and functional evaluation of localized cortical electroencephalographic (EEG) patterns in man have provided a new basis for exploring relationships between EEG patterns and complex sensory- motor performance in man. Using these methods our overall objectives for this research program are: 1) to develop a performance scenario in the laboratory containing sensory-motor tracking and associated functional elements that are consistent with the actual field circumstances encountered by Air Force flight crews, 2) to identify specific EEG and other physiological patterns that can both differentiate and anticipate good vs. poor performance in these tasks, and 3) to implement physiological feedback (i.e., biofeedback) procedures that can be used to train personnel in the recognition of these patterns and to maintain desired functional status in actual field situations. The first year of this project was concerned with initial set-up of laboratory facilities and with a preliminary exploration of various performance tasks and related EEG response patterns.

METHODS

In seeking a laboratory performance task involving realistic visual-motor tracking requirements we explored several commercial video programs available for use with our existing laboratory computer equipment. Four different "games" were evaluated. As shown in figure 1, two of these involved avoidance of random, moving objects, one requiring maneuvering through obstructions towards a goal and the other requiring simple avoidance of moving objects. Two other games simulated actual flight circumstances, with one requiring landing along a specified glide path and the other providing a comprehensive instrument panel for carrying out a designated flight plan.

Six adult subjects, four male and two female, were provided with experience in the performance of each game. Subjects were seated comfortably in front of a TV monitor and provided with manual control devices for "playing" one or the other of these games. Test trials consisted of six repeated 5 min. playing periods separated by 2 min. rest periods, thus providing a 40 min. performance session. Each subject underwent three such test sessions. Performance was measured quantitatively in each session, this measure depending on the game being evaluated.

EEG electrodes were attached bilaterally over somatosensory cortex with conductive paste and cotton pads at C_1-C_5 and C_2-C_4, according to the International 10-20 System. Leads from these electrodes were fed simultaneously to a Grass model 10 polygraph and Crown Vetter magnetic tape recorder, together with a time-code signal to coordinate these two media. EEG signals were evaluated using a standardized power spectral analysis program developed in our laboratory (Sterman, 1981). Successive 16 sec epochs of EEG data from each test

period were digitized and subjected to fast Fourier transform, scaling correction and log transformation. Values for adjacent 4 Hz frequency bands from 0-27 Hz were printed, and means calculated for each 5 min test session. Spectral density distributions were then compared as a function of good vs. poor performance in each game. Statistical analysis employed multiple Analysis of Variance and t-tests for selected comparisons. The 0.05 level of probability was required for significance in each comparison.

RESULTS

A. Comparison of Video Game Tasks:

In evaluating the four video games tested we considered their structure, ease of application in an extended test scenario, and relevance to this project. Two of the games required discrete trials with a specific starting configuration and a final objective ending each trial [i.e., reaching safety (A) or landing the aircraft (C), in figure 1]. The other two allowed for continuous performance. However, the missile dodging game (B in figure 1) was inappropriate for an extended scenario since consistency over time could not be assumed. The longer the operator avoided collision the faster the missiles moved.

This left the F-16 flight scenario game (D, figure 1). Starting the task with the aircraft "in flight" provided for continuous tests of response capability. If designated flight instructions were pre-determined the difficulty factor could be kept constant across prolonged testing. Finally, the flight simulation paradigm was relevant to our interests. For all of these reasons it was decided to employ this video program in our next study. It should be pointed out, however, that the slow sampling rate and relatively primitive graphics of this program greatly affected the interest in and accuracy of this test. It was selected because of a perceived necessity to proceed with our next study using what was available at this time, rather than a great degree of satisfaction with this particular test.

B. EEG Correlations With Performance:

Significant differences were observed in somatosensory EEG spectral profiles between good and poor performance in all of the video games tested. In all but the missile dodging game good performance was associated with an increase in power at 4-7 Hz and to some extent in the adjacent 8-11 Hz band as well (figure 2-A). By contrast, differences noted in the missile dodging game, which required constant and increasing vigilance, were focused in higher frequency bands. In this case poor performance was associated with elevated power, primarily in frequencies above 15 Hz.

DISCUSSION

This study has provided preliminary evidence in support of our primary assumption, namely that quantitative aspects of the somatosensory EEG are indicative of performance characteristics in visual-motor tracking tasks. Specifically, spectral densities between 4-11 Hz appear to be increased with good vs. poor response in most of the tasks evaluated. Further data analysis will be required to determine the relationship of these changes to baseline characteristics, and more subjects must be studied to assure the validity of these observations. Nevertheless, this observation is consistent with previous findings that have related power in these frequency bands to sensorimotor excitability in animals (Bouyer et al., 1974; Sterman et al., 1969; Sterman and Bowersox, 1981).

It is interesting to note that the one task requiring constant vigilance appeared to produce EEG density differences restricted to the higher frequency bands. Good performance was associated with reduced power at these frequencies. Since power at higher frequencies is indicative of increased arousal (Rougeul et al., 1979), these findings suggest once again that excessive arousal is detrimental to steady performance, a fact well established in the literature.

From the standpoint of our basic objectives the following suggestions may be considered for future studies:

1. Given present resources, the F-16 flight simulation video game seems to be the most appropriate game tested and could be used in future studies.

2. Central (somatosensory) EEG placements are desirable and should be a focus for quantitative analysis. However, other sites should be evaluated as well in order to localize these correlations and to seek contrasting patterns. In this regard, occipital (visual) placements seem desirable.

FIGURE LEGENDS

Fig. 1. Examples of TV screen images associated with four different video game tests used to evaluate EEG spectral density changes during good and poor performance. See text for details.

Fig. 2. Power spectral density distributions derived from somatosensory cortex EEG (C_1-C_5, International 10-20 System) during 5 min. samples of sustained good (solid curve) and poor (dashed curve) performance in two different video game tests. Data at A are from two different subjects involved in targeted tracking task (fig. 1-A), while those at B are from two subjects engaged in evasive action task (fig. 1-B). Differences seen were reliable and significant.

Figure 1.

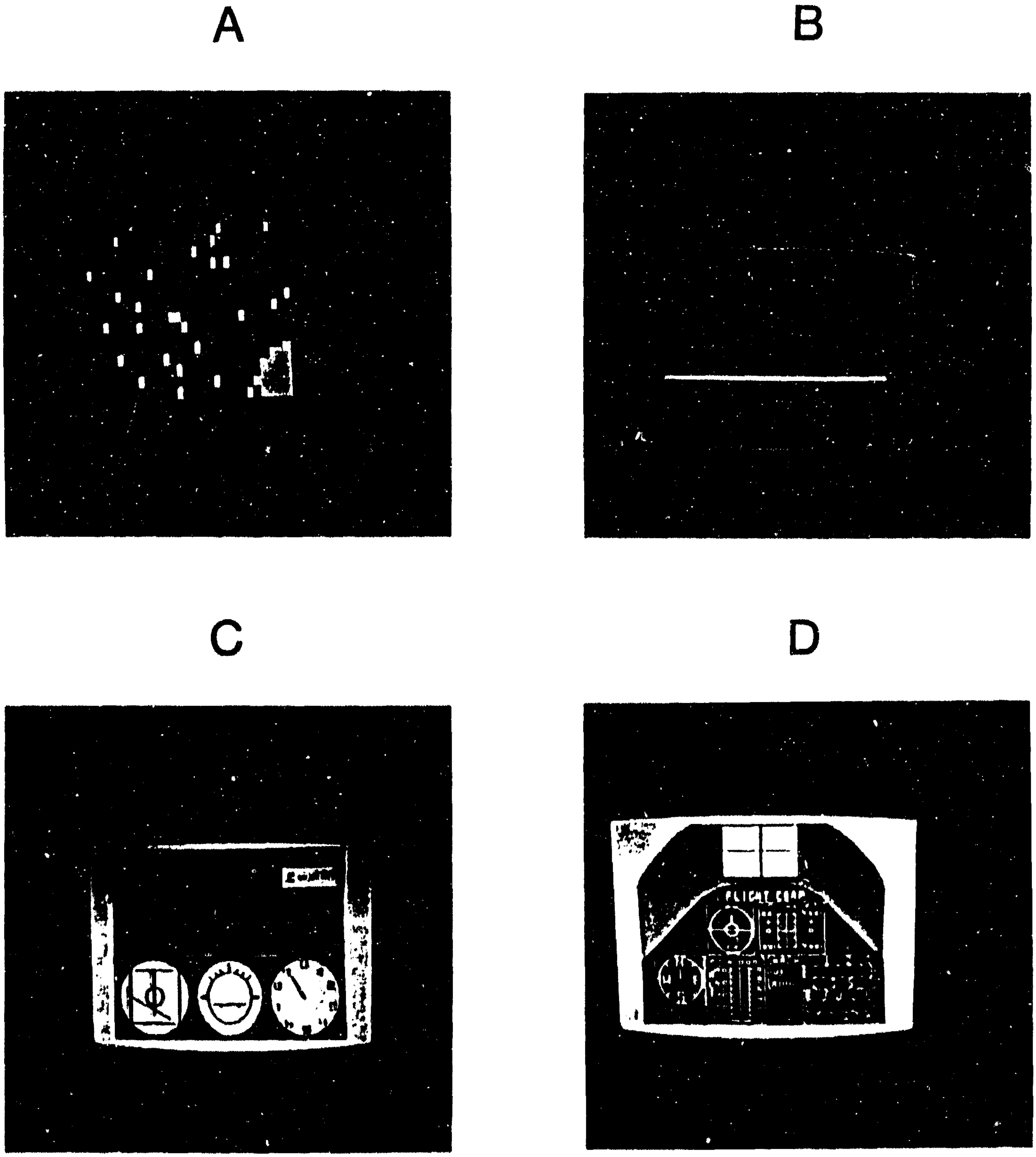
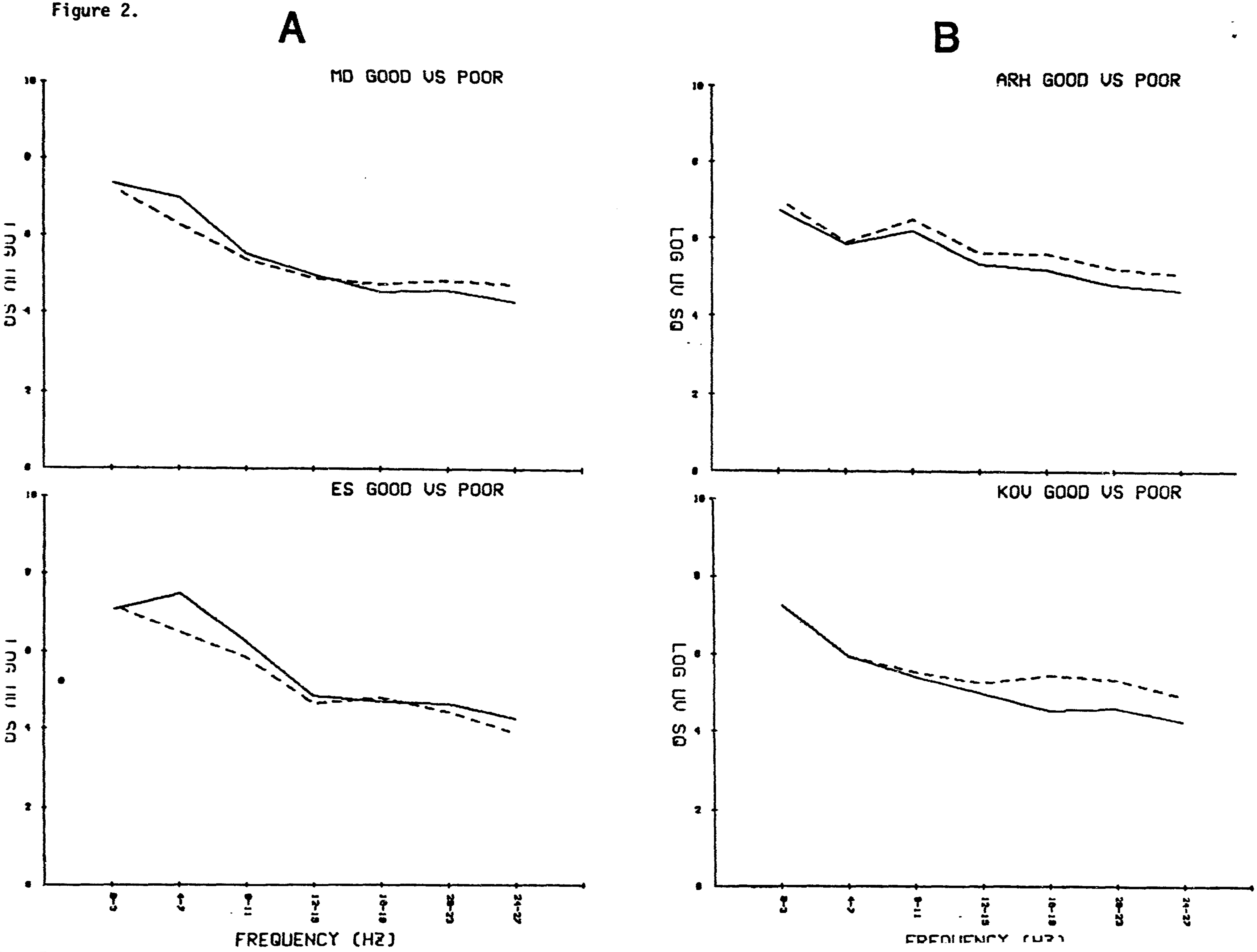


Figure 2.


A
B
MD GOOD VS POOR
ES GOOD VS POOR
ARH GOOD VS POOR
KOV GOOD VS POOR
LOG UV SQ
FREQUENCY (HZ)

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